High Power Panels to Enable High-Performance CubeSat Missions

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High Performance CubeSats

Outline

• **New Systems**
  – Deployable Array
  – Gimbal
  – Propulsion
  – Comm.

• **Lessons Learned**

• **New Mission Capabilities**

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• **New Systems**
  – Deployable Array
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  – Propulsion
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Deployable Array Overview

- **Power System Goals:**
  - Low volume
  - High reliability/low risk
  - Simplified operation

- **12x 2mm thick composite panels**
  - 3 panels per side of the CubeSat

- **80W peak and 49W OAP delivered from PPU**

- **Full hemispherical pointing achieved by the Gimbal mechanism**

- **Developed via the Army SBIR program**
**Composite Solar Panels**

- Carbon fiber structure composed of unidirectional and woven fibers strategically placed for stiffness profile
- Each panel 1 mm thick plus 1 mm rails around cells
- Embedded Cu tape reduces need for wiring on panels
- Built-in hinge features reduce part count and increase manufacturing reliability
- Outer panels’ cells face away from body providing the option for pre-deployment power

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Deployable Array CONOPS

• **Discrete movement of the panels**
  – Gimbal can move panel 2.5° ahead of incidence angle and then power down until panels fall 2.5° behind incidence angle

• **This operation scheme allows for power savings by powering down the motors and relying on the detent torque through the gearhead to hold the panels in place.**

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• Carbon fiber panels will be 78% covered by solar cells
• Due to panel thinness, good thermal conduction to the back side allows comparable radiative cooling to Al

Incident Solar Flux (1370 W/m²)

Radiative Cooling (to 3K space)

Panel has high through-thickness thermal conductivity

Configuration | Panel Temp
--- | ---
Al Panels | 64 C
CF Panels | 65 C
PCB Panels | 71 C
Body Mount | 124 C

Panel Design Maximizes Cell Efficiency and Shades CubeSat Body
"Carpal-Wrist" Gimbal

- **3 stepper motors achieve 3 DOF**
  - Hemispherical pointing on nearly any radius
- **Gimbal motivates panel deployment**
  - No added actuators needed
- **Mechanism designed for accuracy over an extended lifetime**
  - Simulated 3 years of orbital motion and maintained accuracy to remain within 1% of peak power
- **No cable windup**
  - Gimbal mechanism does not twist, allowing cables to easily pass through mechanism
- **Qualified to CDSv12 requirements**
Gimbal Video
Water Electrolysis Thruster (WET) Propulsion

- On-orbit electrolysis of water into $gO_2$ and $gH_2$ enables high-$I_{sp}$ propulsion while avoiding stored energy on launch to conform to P-POD requirements
- High-thrust rates: up to 6 m/s of $\Delta v$-per-orbit for a 3 kg CubeSat
- 500 $\mu$N-s bit-impulse, appropriate for attitude control and station keeping
- Modular, stand-alone propulsion module
Scalable Propulsion

- The WET propulsion unit is highly deformable and can be easily scaled to a desired total impulse or interior volume form factor
- Favorable scaling: 300 Ns per 100g of water (100 m/s $\Delta v$ for a 3 kg CubeSat)

- The thruster can be designed to fit in the interior volume of the PPOD pusher-plate spring, freeing the 3U volume

- Completely green propulsion system, using de-ionized water
- The advantage over similar-scale electric propulsion approaches is the higher $\Delta v$ available per orbit and the cleaner exhaust plume of the $\text{H}_2/\text{O}_2$ rocket.
Power Enabled Communications

• More power enhances CubeSat communications
  – More power $\rightarrow$ higher EIRP (radiated power)
  – Higher EIRP $\rightarrow$ faster data rates
  – Higher EIRP $\rightarrow$ more link margin
  – More sophisticated processing w/ SDRs
    • Lower bit error rates
    • Spectrally efficient waveforms $\rightarrow$ faster data rates
    • Improved filtering for spectral mask compliance
    • Digital predistortion maintains spectral efficiency over system lifetime
SWIFT-SDR™ CubeSat Radios

- **Unprecedented capabilities for CubeSat applications**
- **Programmable**
  - FPGA-based w/ lots of RAM and Flash
- **Flexible**
  - Multiple RF frontends to support different bands
  - Flexible host spacecraft interfaces
  - 100% runtime programmable
- **Compatible**
  - 82mm square for Colony-II bus
  - Type-1 encryption ready
- **High performance**
  - >100 MHz bandwidth
  - 100% phase coherent
- **Reliable and fault tolerant**
  - Latchup detection and protection
  - Thermal and power monitoring
SWIFT-RelNav™

- Cluster navigation, communication, and timing
- **Performance**
  - < 0.1 m ranging precision (1-σ)
  - < 1° attitude precision (1-σ)
  - Crosslink data rate > 15 Mbps
  - Timing synchronized to < 20 ns (1-σ)
  - No sensor pointing required
  - No external references (i.e. GPS) required
  - Scalable to large number of spacecraft
  - Specified performance up to 10 km
- **SWaP**
  - 82 x 82 x 25 mm
  - 0.4 kg
  - 3.2 W RX
  - 6.9 W peak TX

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• Simultaneous dual-band receiver
  – SGLS: 1760-1840 MHz
  – USB: 2025-2100 MHz
• >1W transmitter
  – S-band: 2200-2300 MHz, > 30 MHz BW
• Encryption ready
  – Integrated AES-256 encryption
  – Compatible w/ Type-1 encryption
• 100% runtime programmable
• Coherent turn-around ranging
• SWaP
  – 82 x 82 x 25 mm
  – < 0.4 kg
  – 3.2 W RX
  6.9 W peak TX
**SWIFT-TacSatComm™**

- **System to communicate w/ standard Army issue handheld radio**
- **Dual-band transceiver**
  - UHF @ 56 kbps
    - > 4 W transmit power, with EIRP > 10 W
  - S-band backhaul link
  - Encryption, FEC, Doppler compensation
- **High gain antenna**
  - Deployable
  - Steerable w/ gimbal
- **SWaP**
  - Size: 0.5-1U
  - Power: < 14.7 Watts

[Image of SWIFT-TacSatComm™ system]

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New Mission Capabilities

- Orbit Agility for Reconfigurable CubeSat Constellations
- Cis-Lunar CubeSat missions
- Orbital Debris Remediation using CubeSats
Advanced Propulsion, Power, & Communications
For Space, Sea, & Air